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A legislative solution to acid deposition

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Abstract

In the 1990 Clean Air Act Amendments (CAAA), Congress enacted acid deposition controls to reduce sulfur dioxide (SO_2) emissions by 10 million tons below 1980 levels utilizing a market-based emissions trading program. In recent years, research on the combined effect of SO_2 and nitrogen oxides (NO_x) strongly suggests that the CAAA of 1990 will not be adequate to ensure a recovery of sensitive ecosystems, such as the Adirondack mountains and other effects associated with the same pollutants, such as those observed in the Chesapeake Bay. New legislation is needed to further reduce, in the most cost-effective manner, SO_2 and NO_x emissions to mitigate these continuing acid deposition effects. Senators Daniel Patrick Moynihan (D-NY) and Alfonse M. D'Amato (R-NY) recently introduced the Acid Deposition Control Act of 1997 (S. 1097) which requires an additional 50% reduction of SO_2 and a 70% reduction in the level of NO_x emitted from electric utilities. The legislation accomplishes these reductions by lowering the existing emissions cap on SO_2 and by initiating a new cap-and-trade program for NO_x. In addition, the Act directs the Environmental Protection Agency (EPA) to develop ecological objectives for those ecosystems that are particularly sensitive to acid deposition. These objectives are to be evaluated on a four-year basis with the results reported to Congress. If significant progress in achieving these objectives is not obtained, the Act directs the EPA to take appropriate policy actions.

Keywords: Acid deposition; Clean Air Act; Cap-and-trade; Environmental Protection Agency; National Acid Precipitation Assessment Program

1. Introduction

In 1990, Congress enacted the Clean Air Act Amendments (Public Law 101–549) to modify and reauthorize Federal regulations on various air pollutants. With the enactment of the Clean Air Act Amendments (CAAA), Congress addressed the issue of acid deposition for the first time. Title IV of the CAAA specifically addressed the detrimental effects of acid deposition on ecosystems by mandating reductions in emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) – major precursors of acid deposition from electric utilities. The benefits expected by Congress included decreases in the acidity of surface waters; recovery of fish diversity and abundance; reversal of soil degradation; decreases in forest stress, particularly on high elevation sites; visibility improvements of scenic areas; decreases in damage to buildings and cultural resources; and improvements in human health (EPA, 1995).

To achieve reductions in acid deposition, Title IV targeted emissions from electric utilities which were, and remain, major sources of both SO_2 and NO_x (Fig. 1). Annual emissions of SO_2 are to be reduced by roughly 10 million tons from 1980 levels under an innovative market-based allowance trading program. The program allows utilities to comply with SO_2 emission reduction requirements by either reducing emissions or by purchasing pollution credit allowances. Each credit is equal to 1 ton of SO_2 emissions. Allowances may be traded while a 'cap' is maintained on SO_2 emissions nationwide. The trading program provides utilities with flexibility and promotes innovative measures in reducing emissions to yield pollution prevention benefits while minimizing compliance costs. When the SO_2 cap-and-trade program is fully implemented in 2010, emissions of SO_2 from effected utilities will be capped at 8.95 million tons per year.

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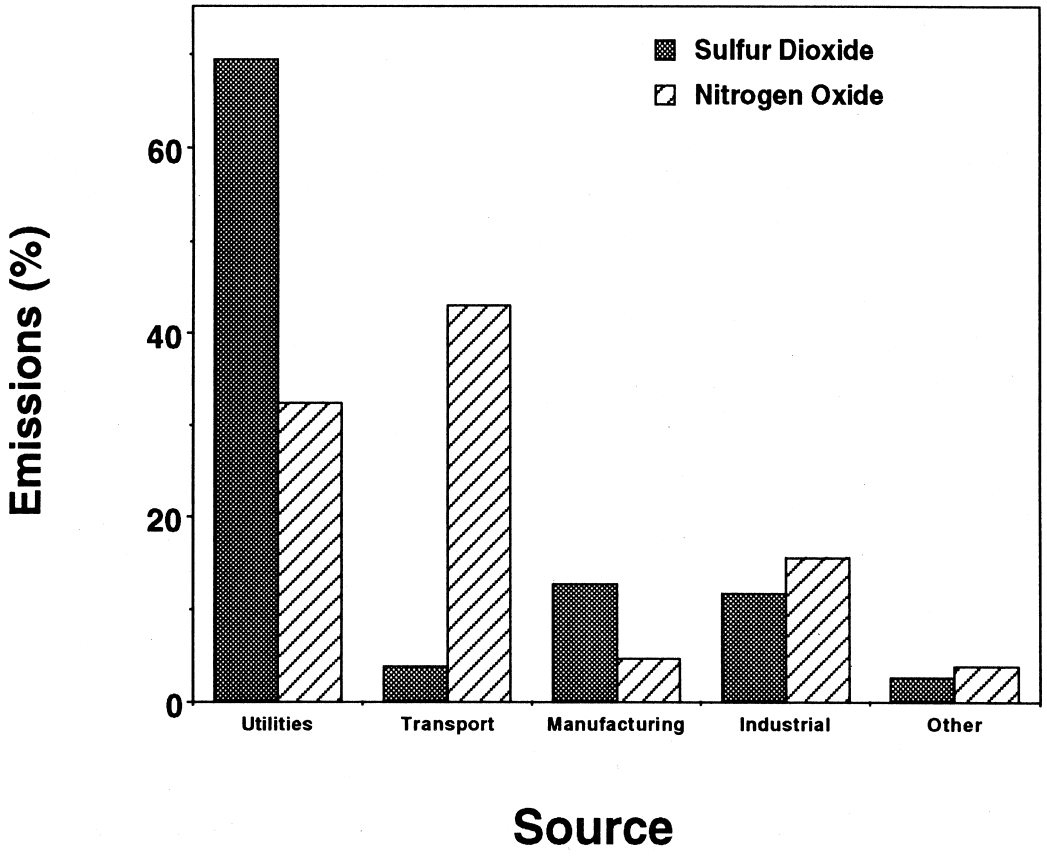

Fig. 1. Percentages of utility emissions by source for sulfur dioxide and nitrogen oxides. Source: NAPAP Emissions Inventory, November 1989.

Title IV also specified that standards be set for NO_x emissions from utility boilers with the goal of reducing nationwide emissions by 2 million tons from 1980 levels. Unlike the SO_2 program, the NO_x program did not establish a cap-and-trade system, but instead called for the installation of low-NO_x burner technology to reduce emissions (Parker, 1996).

Since the authorization of the 1990 CAAA 8 yr ago, measurable reductions in emissions of both SO_2 and NO_x have been achieved, though greater reductions have been obtained by the SO_2 cap-and-trade program (Figs. 2 and 3). Since 1990, reports made by the Environmental Protection Agency (EPA, 1995) and the National Acid Precipitation Assessment Program (NAPAP, 1998) have concluded that projected reductions in total acid deposition resulting from emission reductions will likely not be sufficient to ensure the recovery of sensitive ecosystems, particularly in the eastern United States. Moreover, a recent report from a workshop attended by leading aquatic and watershed ecologists concluded that coastal water bodies are being seriously affected by atmospheric deposition of nitrogen (ESA, 1997). Senators Daniel Patrick

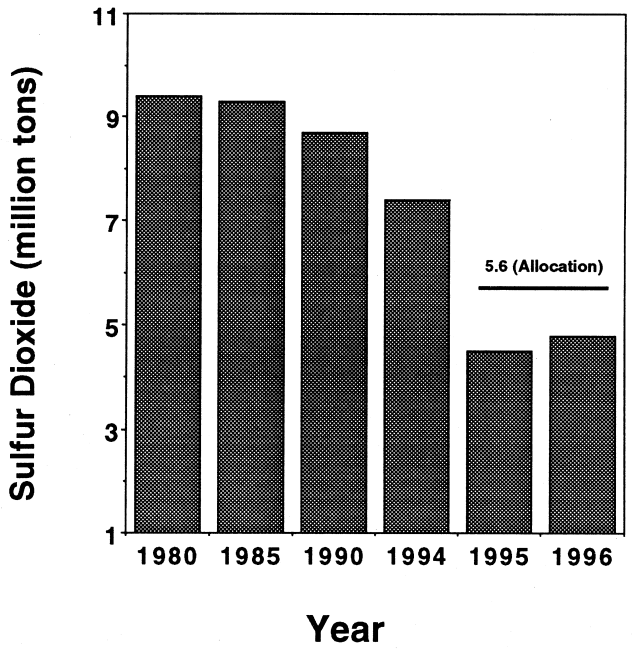

Fig. 2. Annual sulfur dioxide emissions (millions of tons) from 263 utilities affected under Title IV of the CAAA over a 16 yr period beginning in 1980. Source: EPA, 1996.

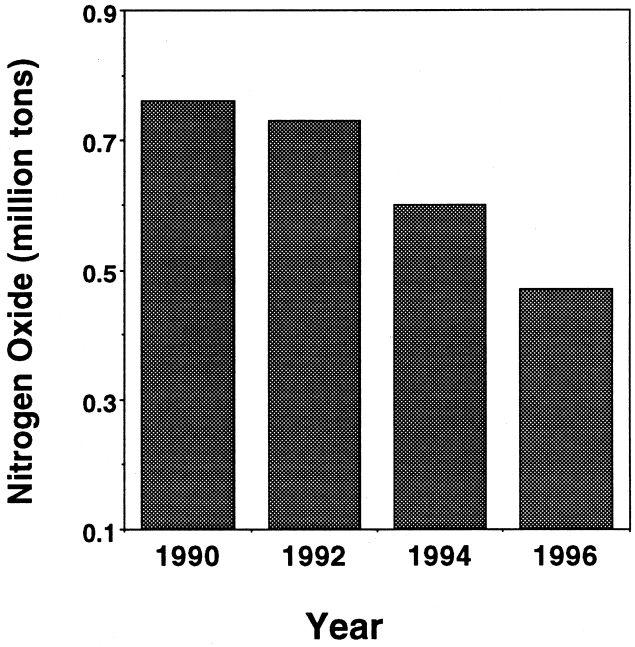

Fig. 3. Annual nitrogen oxide emissions (millions of tons) from 239 utilities affected under Title IV of the CAAA over a 6 yr period beginning in 1990. Source: EPA, 1996.

Moynihan (D-NY) and Alfonse M. D'Amato (R-NY) recently have introduced legislation to address the continued problem of acid deposition. Entitled The Acid Deposition Control Act of 1997 (S. 1097), the act seeks to reduce emissions of SO_2 and NO_x beyond the reductions imposed by the CAAA of 1990. The purpose of this paper is to (1) discuss the historical context from which this new legislation has emerged, (2) suggest ways in which environmental policy can best manage the acid deposition problem and (3) present a summary of Senator Moynihan and D'Amato's bill.

2. Historical context

Senator Moynihan initiated The National Acid Precipitation Assessment Program (NAPAP) in 1979 with the introduction of his bill The Acid Precipitation Act, which subsequently became Title VII of the Energy Security Act of 1980 (Public Law 96–294). The role of NAPAP was to develop the scientific basis for a federal policy regarding acid deposition. After 10 years of research and the expenditure of over US$500 million, NAPAP published a report on the causes and effects of acid deposition on ecosystems, structures and human health (NAPAP, 1991).

With the release of the report there were divergent interpretations of the scientific results described by the media, making it difficult for the public and policy makers to understand the implications of the reported research. On one end of the spectrum, the environmental community held that acid deposition was a widespread problem with many examples of visible deleterious ecological responses (e.g., NRDC, 1991). On the other end, industry, utility groups and midwestern states held that acid deposition was not a widespread problem, but rather a problem limited to just a few highly sensitive ecosystems (e.g., Krug, 1990). Unfortunately, the media focused on these opposing interpretations and ignored the scientific community's interpretation, which we summarize in the following way: while there was some uncertainty in the results and difficulty in showing statistically significant cause and effect relationships with data collected to that time, acid deposition was a significant problem that needed to be considered in the reauthorization of the Clean Air Act. Even with such uncertainty, scientists concluded that freshwater aquatic ecosystems were being affected by acid deposition, particularly from deposited sulfur (e.g., Driscoll et al., 1985; Schindler, 1988). Moreover, tree decline in high elevation conifer forests was indirectly linked to high acid deposition rates (Shortle and Smith, 1988). Of greater uncertainty were the long-term chronic effects of acid deposition on soil in hardwood forest ecosystems. A mechanism for soil acidification was postulated; however, at the time the NAPAP report was written scientists remained unsure of the net effect of acid deposition on forest soils in general (Weathers and Lovett, 1997).

The reason for the uncertainty and difficulty in establishing cause and effect statistical relationships was partly due to the complex nature of ecological systems. For example, many factors other than air pollution affect forest growth and health (Cowling, 1989; Hinrichsen, 1986; Tamm, 1989). Indeed, extensive research has shown that many air pollutants, by themselves, affect tree performance. When these air pollutants affect trees collectively and in combination with other environmental stresses, there are likely to be greater and often unexpected effects (Likens, 1989; Weathers and Lovett, 1997). Moreover, trees are long-lived organisms relative to human life spans and require observations over relatively long periods of time.

Exploring statistical relationships between a complex of environmental factors and long-lived organisms requires controlled experimentation and the obtainment of large numbers of observations over space and time (Tamm, 1989). These difficulties imply that we need to study ecosystem responses to air pollutants over decades rather than years and across an array of ecosystem types – datasets that were for the most part unavailable at the time the NAPAP report was published. Certainly, we recognize there were both critical and complimentary views of the report and with the

NAPAP process (see Likens, 1992; Moynihan, 1993; Schindler, 1992, among others). But rather than provide an exhaustive overview of these viewpoints, we will focus on one unavoidable problem associated with the final report: the paucity of long-term data at the time the report was written. We propose that this lack of data had much to do with both the perceived and actual uncertainty regarding acid deposition effects expressed by the scientific community. Moreover, the quest by the scientific community to arrive at a consensus regarding the meaning of the data further mired efforts to disseminate the findings of NAPAP (Moynihan, 1993). The attempt to reach consensus over a limited set of data observations conveyed a mixed message that confused the public and policy makers alike. This confusion, in combination with the late release of the report (the report was released after the CAAA were introduced in Congress), resulted in mandated reductions in utility emissions under the CAAA for SO_2 (50%) and NO_x (~10%), reductions that were not, in our opinion, tied to clearly defined environmental objectives. In other words, at the time the 1990 CAAA became a law, it was uncertain whether these reductions would lead to the recovery of sensitive ecosystems.

2.1. The need for long-term studies

What has been lost in the controversies surrounding the 1990 NAPAP report was the recommendation by the scientific community to conduct research and long-term monitoring across an array of ecosystems (NAPAP, 1991). Indeed, NAPAP itself created a network of long-term atmospheric deposition monitoring stations, permanent forest plots, and lake sampling regimes (Weathers and Lovett, 1997). NAPAP also led to the issuance, directly or indirectly, of over 70 doctoral degrees to students in acid deposition research, many of whom have formed a nucleus for acid deposition research in the last decade (Weathers and Lovett, 1997). During the 1980s, when NAPAP was in full operation, the National Science Foundation initiated the long-term ecological research (LTER) network, which now has 20 sites throughout North America and the Antarctic. The mission of the LTER network is to conduct and nurture ecological research occurring over greater than usual spatial and temporal scales and to create a legacy of long-term experiments and observations for the use of future generations. With this physical and institutional infrastructure to monitor and study ecosystems over long periods of time, scientists were given the opportunity to analyze 10–20 years databases across a suite of ecosystem types. One site, the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire, has now continuously collected data for 35 years (Likens et al., 1996). Collectively, these analyses have decreased the uncertainty in the scientific community's understanding of acid deposition effects that existed in 1990.

2.2. Current scientific understanding

We provide here a general description of current knowledge regarding the effects of acid deposition on ecosystems. Our intent is not to provide an exhaustive review of the literature, but to show the significant advances in our understanding of acid deposition effects since the completion of the 1990 NAPAP report.

At the time the NAPAP report was written it was unclear whether forest soils were being acidified, or would ever acidify, due to acid deposition (NAPAP, 1991). Some scientists hypothesized that acid deposition would not cause significant soil acidification because of the enormous pool of base cations found in most forest soils (see Weathers and Lovett, 1997 for a more comprehensive review and discussion). Recent research in North America, however, has shown that both soil acidification and nutrient depletion of soils results from acid deposition in poorly buffered soils, or soils with relatively deficient pools of cations (Lawrence et al., 1996; Likens et al., 1996, among others). This response was first shown in Europe, where acid deposition has been of longer duration and at higher intensities than on the North American continent (e.g., Tamm and Hallbacken, 1986; Ulrich et al., 1980; van Breemin et al., 1982). The significance of these findings is twofold: first, it appears that some soils *can* be chemically altered by acid deposition. Specifically, weathering rates and atmospheric inputs of cations are unable to keep up with the loss of cations through leaching from these soils; second, even with decreases in atmospheric deposition of sulfur (S) and nitrogen (N), the recovery of these soils may take longer than predicted, since previous losses of base cations may have been masked by atmospheric inputs of these cations (Likens et al., 1996), which until recently were above pre-industrial levels in the northeastern US (Hedin et al., 1994). Moreover, once there is a measurable response in a threshold relationship, such as the relationship between soil pH and acid mineral input, changes thereafter can occur very rapidly. In the case of soil acidity, once a measurable response is observed in the soil, the pool of available base cations may be nearly exhausted, which can take many decades to replenish (e.g., Likens et al., 1996).

Perhaps the greatest advance since the 1990 NAPAP report has been in our understanding of N deposition effects on terrestrial and aquatic ecosystems (Aber et al., 1995; ESA, 1997; Vitousek et al., 1997). During the late 1980s several scientists hypothesized that with

sustained N inputs from atmospheric deposition, the biological demand in what are normally N-limited forest ecosystems, will be exceeded (or *saturated*), leading to diminished forest health and greater losses of N from what are generally retentive ecosystems (Aber et al., 1989; Ågren and Bosatta, 1988; Skeffington and Wilson, 1988). Indeed, recent research has shown that chronic additions of N have resulted in increased losses of N from sensitive forest ecosystems (Aber et al., 1995). Losses of N from forested ecosystems can be accompanied by depletion of base cations and increases in soil and water acidity (e.g., Boxman et al., 1995; Emmett et al., 1995). Much of the loss of N from terrestrial systems is in the form of nitrate which can have a serious impact on surface water quality. In fact, atmospheric deposition of N is estimated to contribute 10–40% of the new N (as opposed to N recycled within an ecosystem) impacting coastal water bodies in the eastern United States (ESA, 1997; Table 1). Moreover, it is hypothesized that N-saturated ecosystems will have higher trace gas emissions of N (Aber et al., 1989), which may be causing increased atmospheric concentrations of these important greenhouse gases (Vitousek et al., 1997).

The link between acid deposition and forest health was difficult to demonstrate when the NAPAP report was completed in 1990 partially for reasons previously mentioned. More recently, the effects of the documented changes in soil chemistry discussed above have been shown to lead to nutrient imbalances in trees (Aber et al., 1995). Such imbalances have been linked to tree growth and forest decline in both high and low elevation forests (e.g., Shortle and Smith, 1988; Wilmot et al., 1995; Wilmot et al., 1996). How widespread these forest health effects are manifested is currently unknown. Nitrogen deposition, however, appears to have the potential for more widespread effects than S deposition since N, unlike S, is often a limiting nutrient in temperate forest ecosystems. Indeed, there are several watersheds in North America that may have reached a condition of N saturation (EPA, 1995; NAPAP, 1998).

2.3. Are more reductions necessary?

Clearly, from what we have learned over the past several years, it appears that additional reductions beyond those mandated in the CAAA are required for both SO_2 and NO_x to protect a wide array of ecosystems. With this perspective, a subsequent policy issue must be addressed: specifically, how much additional emissions reductions are needed? Like many political issues that rely on science for an objective solution, it will not be easy to determine a specific emissions 'threshold' as the cutoff to protect a wide array of ecosystems. Nonetheless, the Congress directed the EPA to conduct an acid deposition standard feasibility study to consider a numeric value, or values, for an acid deposition standard that would be sufficient to protect sensitive aquatic and terrestrial resources (EPA, 1995). EPA's ensuing modeling effort showed that even with complete elimination of S deposition, only a modest number of lakes in the Adirondack mountains would recover by the year 2040 without a

Table 1
Current estimates of nitrogen loading to selected coastal waters attributed to direct atmospheric input. Adopted from Valigura et al. (1996) and ESA (1997)

	Watershed surface area (km^2)	Tidal waters surface area (km^2)	Total load from all sources (millions of kg)	Load from atmosphere (%)
Narraganset Bay	4708	328	5	12
Deleware Bay	36 905	1846	54	15
Long Island Sound	43 481	4820	60	20
Albermarle-Pamlico Sounds	59 197	7754	23	44
Chesapeake Bay	165 886	11 400	170	27
New York Bight	50 107	38 900	164	38
Rhode River	33	4.9	0.012	40
Waquiot Bay	~70	~8	0.022	29
Flanders Bay	83	39	0.36	7
Delaware Inland Bays	800	83	1.3	21
Sarasota Bay	524	135	0.6	26
Patuxent River	2393	137	12.6	13
Newport River Waters	340	225–1600	0.27–0.85	35–80
Choptank River	1779	361	1.54	37
Guadalupe Estruary	–	551	4.2–15.9	2–8
Potomac River	29 940	1210	35.5	5
Tampa Bay	6216	1031	3.8	28
Massachusetts Bays	–	3700	22–30	5–27

concurrent reduction in N deposition (EPA, 1995). In fact, the modeling projected that an additional 50% reduction in SO_2 and NO_x utility emissions beyond the CAAA would benefit the recovery of a majority of acidified lakes and streams in the Adirondack, mid-Appalachian, and southern Appalachian regions, assuming that these ecosystems reach a condition of N-saturation in 100 years (EPA, 1995). More recently, the Canadian Task Group on acid deposition suggested the need for a 75% reduction in SO_2 emissions beyond caps already existing in the US and Canada to protect sensitive lakes in eastern Canada from acid deposition (Environment Canada, 1997). This percentage was calculated on the basis of critical loads, which usually define the highest amount of total acid deposition that will not cause long-term chemical changes of aquatic and forest ecosystems. Critical loads were not determined for N, however, which would have decreased the calculated percentage of S to protect ecosystems, since N is an important component of total acid deposition.

3. What is needed in new legislation?

Over the past 30 years, the US has implemented the most innovative and effective environmental protection system in the world. In the last decade, however, there has been much controversy about whether to continue approaching air pollution control in an identical fashion. Some argue that current 'command and control' environmental laws have reached a plateau in their effectiveness, or have disproportionately burdened certain segments of society. Recent efforts to resolve these issues have resulted in a series of recommendations to reform current environmental legislation (e.g, NAPA, 1997). Here we discuss two pervasive recommendations found in these reports, which we feel are the most applicable and crucial to acid deposition policy.

3.1. Performance-based regulatory system

Both Congress and the White House have directed all Federal agencies, through the Government Performance and Results Act and the National Performance Review, to initiate performance-based management programs. Performance-based management systems entail the establishment of justifiable goals (or objectives) and a periodic assessment of progress toward those goals. In the case of environmental policy, a performance-based system should require a common metric with environmental or biological significance that is measurable over time. For acid deposition policy, the goal or objective should relate to the recovery of ecosystems. As an example, reductions in SO_2 and NO_x emissions from utilities should result in downwind reductions in total acid deposition and an improvement in lake water chemistry, which will eventually lead to more diverse and abundant fish populations, all of which are measurable responses that can be monitored over time.

In utilizing a performance-based system in acid deposition control legislation, there is the option of adjusting the legislation (making the regulations more *or* less stringent) as the response of a specified ecosystem is assessed with regard to the policy action. We propose to refer to this ability to adjust legislative action as 'adaptive policy', much like the terminology used to describe the practice of 'adaptive management' being implemented by several state and federal land management agencies. Empowering an agency with the authority to adjust policy action as advancements are made through monitoring and scientific investigation would ensure more accountability from that agency to Congress. For example, if we learn from the best science available that a particular ecosystem is not recovering according to an established set of scientifically derived objectives, then there is a mandate for the agency to act.

3.2. Flexibility and cost effectiveness

Experience gained with the SO_2 cap-and-trade provision in Title IV of the CAAA of 1990, suggests that when environmental policy allows for flexibility, the costs of attainment are greatly reduced. The SO_2 cap-and-trade program has resulted in greater emissions reductions sooner than required, for far less expense than predicted, and with a perfect record of compliance, unlike the NO_x command and control approach (Ellerman et al., 1997). We provide here a more detailed analysis of how the flexibility afforded by the SO_2 cap-and-trade program has resulted in an over compliance by the utility industry at a much lower cost than what was first predicted.

To attain the goal of reaching a 10 million ton reduction of SO_2 emissions, EPA created a pool of 'allowances' that was equal in number to the permissible number of tons of utility SO_2 emissions. Each allowance represents a limited 'right' to emit one ton of sulfur dioxide, and EPA allocates a specific number of allowances to each utility, basing the size of each facility's allotment on its prior emissions record and required reductions. Utilities which reduce their emissions enough to hold more allowances than they need may sell the excess allowances to other utilities, or they may 'bank' them, saving them for use in a future year. Utilities which cannot cost-effectively reduce their emissions to the required level may buy additional allowances or scale back production in order to meet their emissions budgets.

In addition to contributing to the unprecedented reductions in emissions, the flexibility of the emissions trading program has resulted in plummeting costs of compliance for industry. In 1994, the United States General Accounting Office (GAO) reported that utilizing an emissions trading program to reduce SO_2 instead of traditional command and control techniques, such as the NO_x program, could save US$3.1 billion annually (GAO, 1994). Three years later, GAO announced that the price of allowances has dropped and the level of allowance trading had increased markedly since 1994, suggesting even greater savings (GAO, 1997). For example, the Central Illinois Public Service expected to save US$225 million in a single year as a result of trading. Illinois Power announced savings of US$91 million by purchasing allowances instead of installing scrubbers. Similarly, Duke Power estimated savings of US$300 million and Wisconsin Electric Power Company anticipated saving almost US$90 million because of the compliance flexibility that such a program affords. Additionally, some SO_2-emitting sources are not required to participate in the program voluntarily, but have done so anyway. These sources receive their own allowances, and have the opportunity to reduce their emissions and sell allowances as any participating facility would. Because of the economic incentive for utilities to reduce their emissions early and bank or sell the excess allowances, emissions data indicate that the sources reduced their emissions almost 40% beyond the requirements of the Act (EPA, 1997). Furthermore, the price of attainment (not to be confused with the price for a credit) is a fraction of initial projections. While EPA predicted a cost of up to US$500 per ton of SO_2 removed, the actual average cost of attainment has been approximately US$200 per ton (Ellerman et al., 1997).

4. The Acid Deposition Control Act of 1990

Senator Moynihan, a longtime champion of legislation to control acid deposition, sought to address the need for additional emissions reductions in a manner that would utilize sound science and economics in a smoothly administered process. The result was the Acid Deposition Control Act (ADCA) of 1997, which he introduced on July 31, 1997. Senator D'Amato was an original cosponsor of the bill. On the same day, Congressman Gerald B. Solomon (R-NY) introduced H.R. 2365, an identical bill, in the United States House of Representatives.

ADCA would require a 70% reduction of electric utility NO_x emissions based on 1990 levels, and an additional 50% reduction of electric utility SO_2 emissions beyond the 1990 CAAA levels. Finally, the legislation would call for increased environmental monitoring of industrial facilities' emissions and authorize several ecological research programs.

4.1. Adaptation of emissions trading to NO_x

Pollution credit trading is not a panacea nor is it appropriate and effective in all situations. For example, when very few entities emit a given substance, establishing a market system to trade emissions rights among the emitters may not provide a significant economic benefit. Conversely, when millions of sources generate a given pollutant, it may be impractical to administer a trading program. In other instances, allowance trading in an open market system may lead to a geographic concentration of emissions without specific prohibitions to the contrary. There is good reason to believe that NO_x lends itself to a reduction control strategy which utilizes trading. Roughly a third of the nation's total NO_x pollution stems from electric utilities, another third comes from transportation, and the balance is attributed to industrial processes and off-road diesel engines (Fig. 1). While the costs of further controlling transportation sector NO_x emissions are prohibitively high at present, a variety of reasonably available, practical control technologies exist for use in the utility industry. The universe of NO_x-emitting utilities is large enough to effect a marked decline in national NO_x and ozone pollution levels, yet it is not so large as to be unworkable.

ADCA attempts to adapt the framework of the SO_2 cap-and-trade program to NO_x, retaining its most successful elements while making modifications to address the specific threats posed by NO_x. Like the SO_2 program, the Administrator of the EPA will allocate a fixed number of NO_x allowances, allowing individual utilities to reduce emissions by allowing complete flexibility in compliance choice including purchasing credits from other facilities to comply. Each year, facility officials must conduct an accounting procedure, similar to the SO_2 program, in which they must prove that they hold enough allowances to cover their emissions. If a utility holds too few allowances, it will be fined US$6000 per ton and it must develop a plan to offset the surplus emissions in the following year.

State governments play a vital role in the control of air pollution. Recognizing this the ADCA would promote the participation of the states in implementing NO_x emission reductions. Specifically, ADCA would require the EPA to determine each state's share of the total power generated in the nation based on a rolling 3 year benchmark (Fig. 4), and it would allocate that same share of the nation's NO_x allowance pool to the state government, rather than directly to individual facilities. ADCA then would allow state government offi-

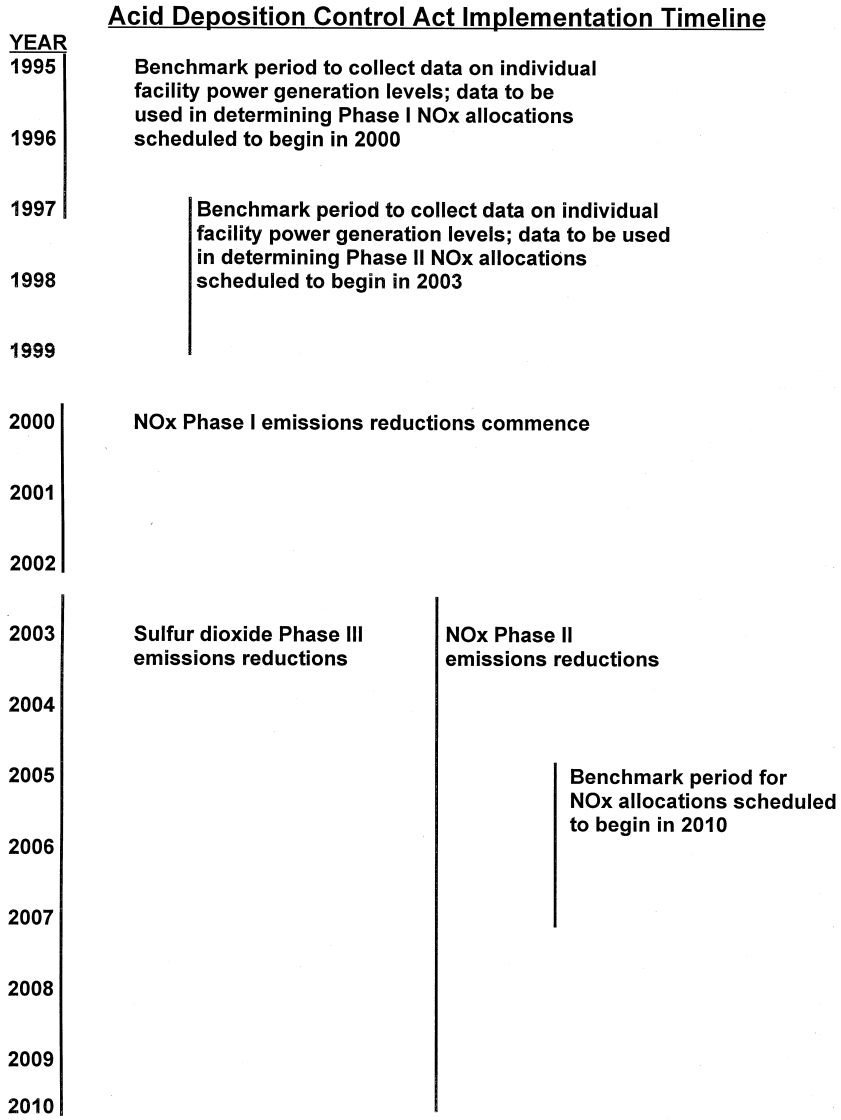

Fig. 4. An implementation timeline for the Acid Deposition Control Act indicating 3 year benchmarks for determining individual facility power generation levels.

cials to determine the allocation of allowances among the utilities in their state(s).

In some instances, it is entirely possible that a state may not wish to engage in the allocation process. For this reason, a state has no affirmative duty to do anything under this legislation. If the deadline passes and a state has not submitted such a report, the EPA simply will distribute the credits to each electric power generator in that state, basing each facility's share of allowances on its proportional share of that state's power generation. The state is not penalized in any way. The aim of the legislation is merely to give those states who wish to participate in the process every opportunity to do so.

ADCA's NO_x trading program provisions differ from the SO_2 trading program in another significant respect. As previously mentioned, the SO_2 program allocates allowances to individual sources based on their emissions history. Essentially, the dirtier facilities are awarded more credits, which constitute an economic good, than utilities which invested early to make their plants run more cleanly. Put another way, utilities which have already likely encountered some economic cost in the service of cleaner air provide a subsidy to plants which have not successfully made a similar investment. In allocating NO_x allowances to the states (and allocating allowances to specific facilities in those states which decline to allocate the allowances themselves), ADCA utilizes a generation performance-based standard. Each state's share of the allowance pool depends on its power generation, not its pollution generation. For instance, if Ohio produces

7% of the nation's total electric power, it receives 7% of the national allowance pool, regardless of its emissions history.

Similarly, in states which do not allocate allowances themselves, EPA is instructed to allot to each facility a share of allowances commensurate with its share of the state's total electric power generation, which is based on a rolling 3 year benchmark (Fig. 4). The winners in this scenario are facilities which can produce substantial amounts of power with comparatively little pollution. They receive a surplus of emissions credits, which they can sell to other, dirtier firms. Because this allocation process would lead to highly polluting plants purchasing credits, the legislation forces such firms to internalize the cost of their emission reductions.

Because NO_x presents a heightened hazard in the summertime, when it interacts with heat and sunlight to form ozone, ADCA's emissions trading program places a surcharge on all NO_x emissions during the months of May–September. During this summer period, utilities must surrender two credits per ton of NO_x emitted, compared to the one credit per ton which they must surrender throughout the rest of the year. By imposing additional costs on emissions during the designated high-risk months, ADCA encourages utilities to deploy additional NO_x-reducing technologies at those times. This 'two-for-one' twist on the traditional market-based trading system means that each allowance spent between May and September is not equivalent to a ton of NO_x emissions. Therefore, an allowance pool of 3.0 million tons will actually translate to roughly 2.3 million tons per year, when the Act is fully implemented. These figures indicate an emissions rate which approximates 0.25 lbs/mmBtus in the winter months and 0.15 lbs/mmBtus in the summertime, figures within the range recommended by the Ozone Transport Assessment Group (EPA memo dated July, 1997).

In states for which EPA allocates allowances, the Agency will initially hold 10% of the credits in a New Source Reserve Fund. From that pool, each new source will receive a share of credits equal to the lesser of the new source performance standard or the permitted level for the full operating capacity of the new facility. The amount of allowances will be adjusted pro rata to reflect the number of months of the year during which the source operates. For the first 5 years of the program, to encourage liquidity of allowances, any remaining allowances in the New Source Reserve Fund will be auctioned. The proceeds of the auction will be returned pro rata to the sources that would have received the allowances had the auction not taken place.

4.2. Sulfur dioxide emission reductions

As we discussed earlier, scientific evidence suggests that further reductions of SO_2 emissions are required to protect an array of ecosystems found to be sensitive to acid deposition and other human health and environmental concerns associated with SO_2 emissions. To that end, ADCA requires an additional 50% reduction in SO_2 emissions by the end of the second phase of the current cap-and-trade program (Fig. 4). Because of the tremendous administrative and compliance success of the present emissions trading program, ADCA will retain the trading system in its entirety and will merely require that utilities surrender two emissions allowances per ton of SO_2 emitted. Except for the effectively lowered cap, all of the other attributes of the program will remain untouched. This provision, therefore, essentially becomes a third phase of the current program.

4.3. Research, monitoring and reporting requirements

To gather better data reflecting the nation's emissions rates and patterns, ADCA would require large industrial facilities to install continuous emissions monitoring systems (CEMS) and report on their emissions in the same fashion that large electric utilities do. In addition, ADCA would authorize a two year study and report to Congress on the feasibility of monitoring mercury emissions from utilities and other large stationary combustion sources. Within a year of the report's completion, the EPA would issue regulations eventually requiring utilities and large industrial sources to monitor their mercury emissions. Based on the monitoring data, EPA would commence a program to regulate mercury emissions from such sources, taking into account technological feasibility, cost, and projected levels of avoided emissions.

The ADCA provides specific direction to EPA to develop a performance-based system whereby the effectiveness of the emissions reductions called for in the Act are evaluated over time. The Act requires EPA to conduct a study identifying scientifically credible environmental indicators which would be sufficient to protect sensitive ecosystems of the Adirondack mountains, mid-Appalachian mountains, the Southern Blue Ridge mountains, the Great Lakes, Lake Champlain, Long Island Sound, the Chesapeake Bay, and any other regional ecosystem determined by the EPA to be sensitive to acid deposition. Based on the findings of the study, EPA would submit to Congress a report on the status and trends of the various environmental indicators for the regions listed above. Furthermore, if EPA determines that the emissions reduction provisions of ADCA are not sufficient to ensure achievement of the environmental objectives, the Agency must

promulgate additional regulations necessary to protect the ecosystems in question. To help develop the environmental indicators, ADCA authorizes a US$10 million competitive grant program to fund research on the health and chemistry of lakes, streams, coastal watersheds, and other ecosystems known to be sensitive to acid deposition.

5. Summary and conclusion

In the previous 8 years, there has been a tremendous increase in our scientific understanding of acid deposition. For the most part, this increased understanding is due to the implementation of long-term ecological and atmospheric studies conducted by various scientists. These studies project that current emission reductions mandated in the CAAA of 1990 for SO_2 and NO_x will not be adequate to prevent the long-term deterioration of sensitive ecosystems such as the Adirondack Mountains, the Appalachian Range, and the Chesapeake Bay. To address this problem, Senators Moynihan and D'Amato introduced the Acid Deposition Control Act of 1997, which builds on the successes of the CAAA of 1990 by extending the current SO_2 cap-and-trade program, initiating a similar cap-and-trade program to control NO_x utility emissions, and mandating the EPA to report on the ecological response of sensitive ecosystems to the emission reductions. Cap-and-trade programs provide utilities with the flexibility to comply with mandated emissions reductions in a cost-effective manner, while the implementation of a performance-based system will ensure that such reductions are adequate to restore sensitive ecosystems.

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